REQUIREMENTS DOCUMENT FOR THE SLR2000
FULLY AUTOMATED SATELLITE LASER RANGING SYSTEM

Background

Satellite Laser Ranging (SLR) is a fundamental measurement technique used by NASA to support national and international programs in space geodesy, ocean and ice surface altimetry, and spacecraft navigation and positioning. The technique, which uses short pulse lasers and fast timing electronics to measure the round trip travel time of a light pulse to satellites equipped with retroreflector arrays, was first developed by NASA/GSFC in the early 1960's as a tool for precision orbit determination and validation of radio tracking techniques. The technique has evolved now to the point where ranging accuracy is at the sub-centimeter level and tracking operations, weather permitting, are nearly continuous.

SLR is a unique tool for the study of the long-term behavior of the Solid Earth because SLR measures the range to passive satellite targets of great longevity. In contrast to radio methods which require regular replenishment of their space sector, SLR can provide uniform range measurements to specific targets over time intervals of decades (and probably centuries, if desired). It measures range directly (through time of flight), rather than being inferred as with other techniques, and, since it is an optical technique, range measurements are not degraded by the refraction uncertainties due to the ionosphere or water vapor variability in the atmosphere.

There are approximately 40 SLR stations operating around the world, routinely tracking satellites as a cooperating network. Ten of the stations are either operated directly by NASA or are NASA systems operated through partnerships with domestic universities and overseas agencies.

The international SLR network is currently tracking twenty artificial satellites with altitudes spanning from near Earth at 500 – 1000 km (for gravity field and altimetry missions) to high altitude missions at 18,000 – 20,000 km (GPS, GLONASS, and Etalon). Another 6 to 8 retroreflector satellites are planned for launch over the next three years.

Although substantial scientific and precision tracking applications have been clearly articulated for SLR (see Shapiro et. al., 1997), major limitations prevent the current SLR systems in the field from achieving their full potential.

1. The operation of the current systems are labor intensive, and maintenance is complicated by the often unique and incremental nature of the hardware and software upgrades that have been used to improve aging systems (some systems are close to 30 years old). Field operations typically cost $400K per year per station.

2. SLR stations that are manufactured today are very costly ($4M – $12 M) due to conventional reliance on large telescopes and tracking mounts, high power lasers, and the need to accommodate their human operators.

3. SLR systems, although using a common general system configuration, have been uniquely designed and built by many different local groups, resulting in lack of hardware, software, and in many cases operational, standardization.

SLR2000

As a means of bringing the SLR technique to its full potential in support of currently envisioned science and applications programs, NASA is committed to the development and deployment of a fully automated, high performance, and relatively low cost SLR system, SLR2000. The practicality of such a system has been made possible through recent technological developments in lasers, detectors, signal processors, and computer systems, which have been developed by industry, in some cases under NASA sponsorship. It is the intention of NASA to replace its current manned SLR systems with the fully automated SLR2000. Other groups will also be encouraged to procure an SLR2000 to replace their aging systems for both cost and standardization reasons.

Requirements

The requirements in this document for SLR2000 are specified in terms of performance. The SLR2000 system should provide:

A. operational performance:

1. unattended, fully automated, continuous operations capability (24 hours/day) for both satellite ranging and calibration;
2. an inherently eye safe beam per ANSI standards at the transmitting telescope which would operate without active aircraft detection systems;
3. day and night-time ranging capability to retroreflector satellites at altitudes between 300 km to 20,000 km;
4. near-hemispherical tracking coverage for satellite elevations above 20 degrees (except for a possible keyhole at zenith of no more than 10 degrees);
5. interleaving of ranging to satellite targets during ranging operations at variable prescribed intervals based on daily scheduling;
6. capability for real-time remote operations and monitoring mode via Internet or telephone; and
7. capability for on or off-site operator intervention;

B. ranging performance:

1. single shot ranging precision of 1 cm for all retroreflector equipped satellites;
2. normal point precision of less than 3 mm on all satellites
3. pass-by-pass range bias of less than 5 mm exclusive of atmospheric refraction;

4. epoch for normal point data within 0.12 microsecond of GPS; and
5. automated measurement and recording of barometric pressure (0.1mb); outside temperature (0.1 degree C), relative humidity (10%); wind speed and direction, day/night cloud cover distribution over the site, precipitation type and visibility determination.

C. automated calibration:

1. eyesafe ranging to an external calibration target
2. automated star calibration and mount modeling to correct pointing errors;

D. automated operations scheduling, planning and orbit prediction capability;

1. ability to pick up tracking predicts in GEODYN output vector format from a designated source;
2. ability to routinely generate pointing commands from vectors;
3. ability to get prediction updates via internet or modem on a daily basis;
4. ability for decision making for revising daily tracking strategies based on satellite schedules, priority, and recent tracking history; and
5. ability to revise or temporarily terminate operating schedules based on cloud cover, precipitation, wind, temperature extremes, or limited visibility at the site;

E. automated data system:

1. on-site processing and evaluation of satellite range data in real-time using short arc orbital analysis with appropriate filtering techniques;
2. on site storage capability for up to one week of normal point ranging data (in case of communication failures) with provision for routine downloading via Internet (or backup modem) and for remote query and retrieval;
3. transmission of stored normal point satellite and calibration range data on a daily or sub-daily schedule in standard CSTG format via Internet (or backup modem) ;
4. transmission of data and system diagnostic and status information on a daily or sub-daily basis in a prescribed format; and
5. automatically maintained historical file of operations and diagnostic information with ready access for retrieval;

F. system maintenance and repair:

1. modular design for ease of repair;
2. a demonstrated mean-time between failures rate (requiring on-site technical intervention) greater than 4 months excluding minor unskilled maintenance tasks;
3. maximum use of commercially available components;

4. rapid, automated system diagnosis and notification via Internet (or backup modem) of system faults, failures, and degradation in performance;
5. comprehensive system maintenance and performance status reporting;
6. a ranging simulation mode to demonstrate laser ranging system functionality;
7. complete electronic documentation for training, operations, and repair; and
8. automated diagnostic warning to network monitor;

G. facilities and safety:

1. automated protection from the elements and loss of utilities at all times (automatically reverts to protected mode);
2. ability of system to automatically shut all or part of itself off due to sensed unsafe conditions and to send an emergency message to network monitor
3. reasonable access for maintenance under environmental protection;
3. routine housekeeping at regular intervals by unskilled labor; and
4. no optical, electrical, or chemical hazards to unauthorized personnel;

H. communications:

1. communications via Internet with phone line backup;
2. capability for data base query via emulation software;